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(54) LED LUMINAIRE HAVING GROOVED MODIFIER

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(51) **Int. Cl.**

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F21V 5/02	(2006.01)
F21Y 101/02	(2006.01)
F21Y 105/00	(2006.01)

(52) **U.S. Cl.**

CPC ... ***F21V 5/04*** (2013.01); ***F21V 5/02*** (2013.01); *F21Y 2101/02* (2013.01); *F21Y 2105/001* (2013.01)

(58) **Field of Classification Search**

CPC F21V 3/02; F21V 5/046; F21V 5/048; F21Y 2105/001; F21W 2131/103; G02B 3/04

USPC 362/145, 249.01, 249.02, 249.13, 294, 362/311.01, 311.02, 363, 373, 307, 308, 362/309, 310, 800

See application file for complete search history.

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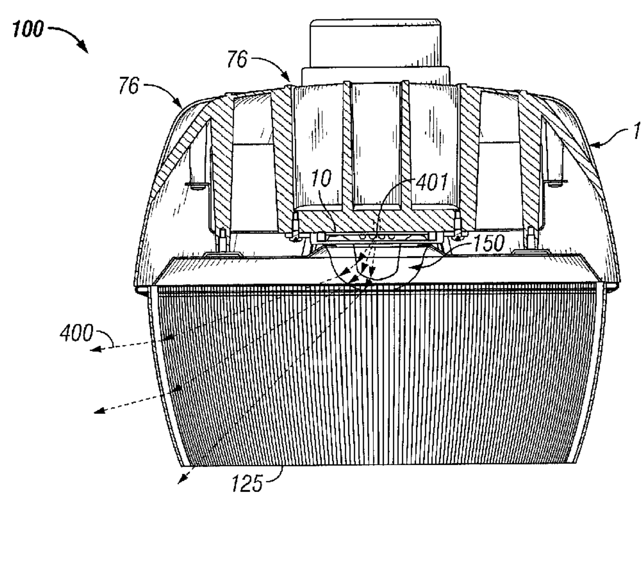
(57) ABSTRACT

A lighting system includes an array of domed light emitting diodes covering a surface area of a substrate and two optics for processing emitted light. The first optic includes an inner surface facing the array and an exterior surface facing away from the array. The second optic includes grooves extending away from the array. The inner surface of the first optic can form a cavity that is large relative to the array. For example, the cavity can have a volume exceeding the volume of a cube, where each side of the cube has the surface area of the array.

18 Claims, 8 Drawing Sheets



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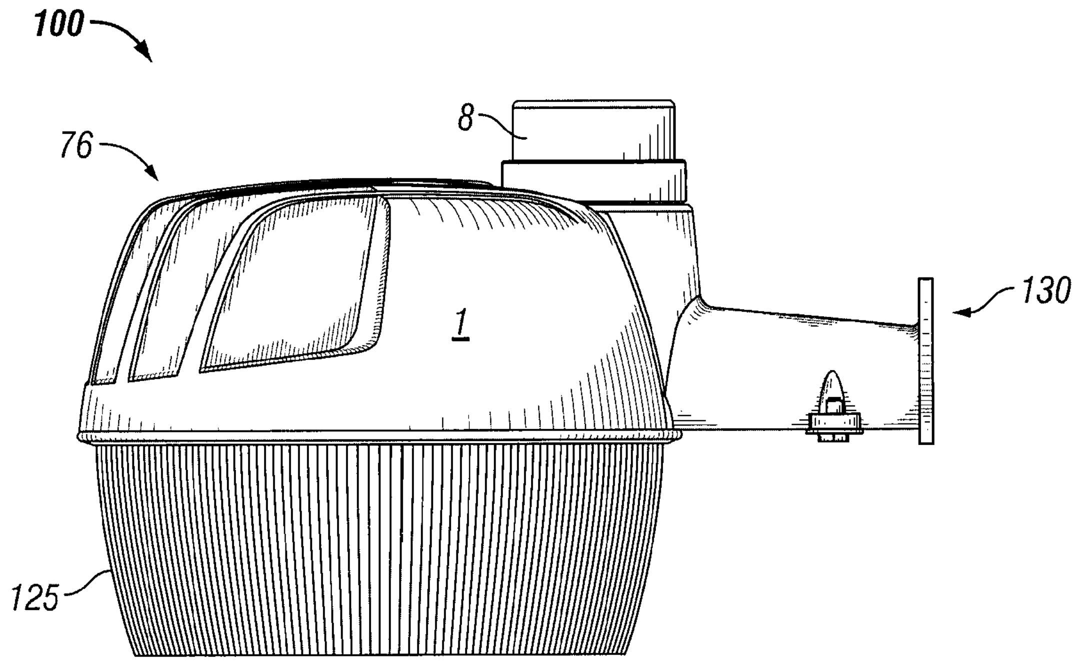


FIG. 1A

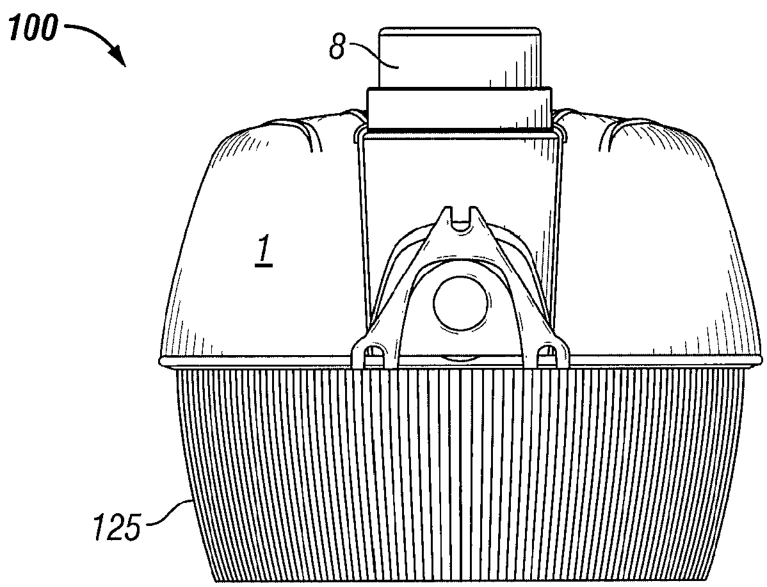


FIG. 1B

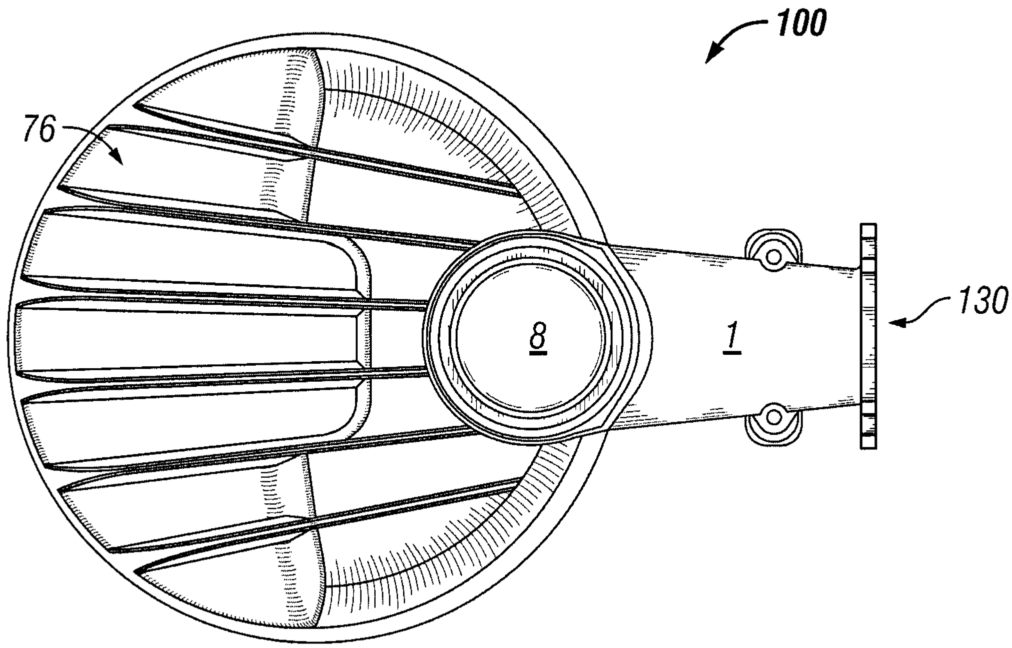


FIG. 1C

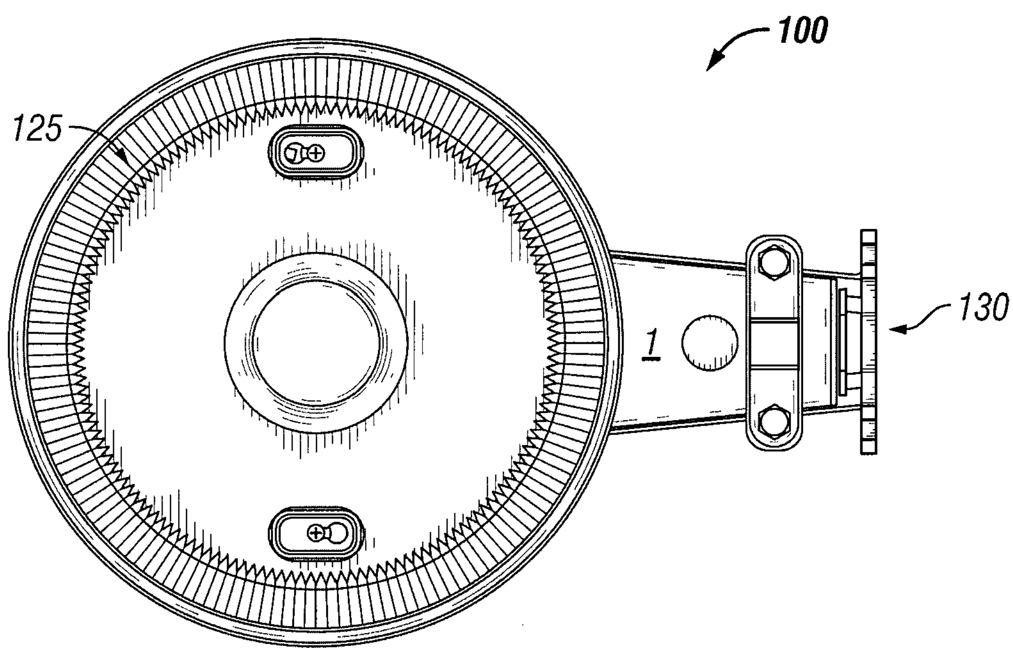


FIG. 1D

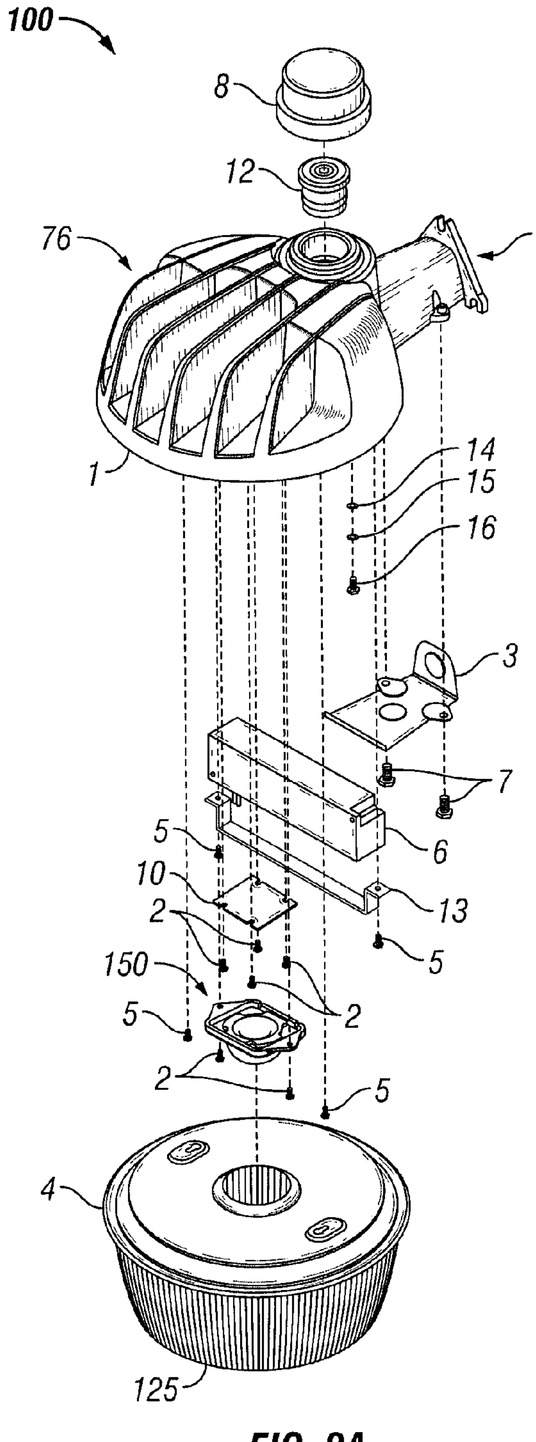


FIG. 2A

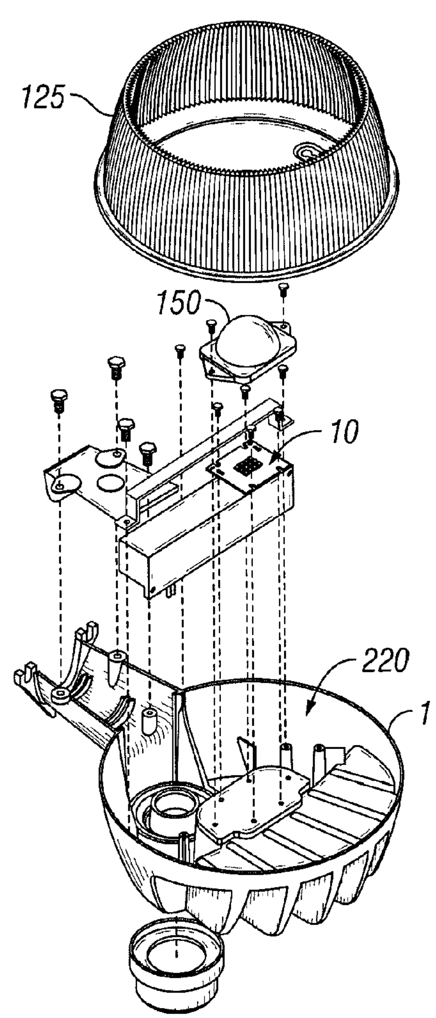


FIG. 2B

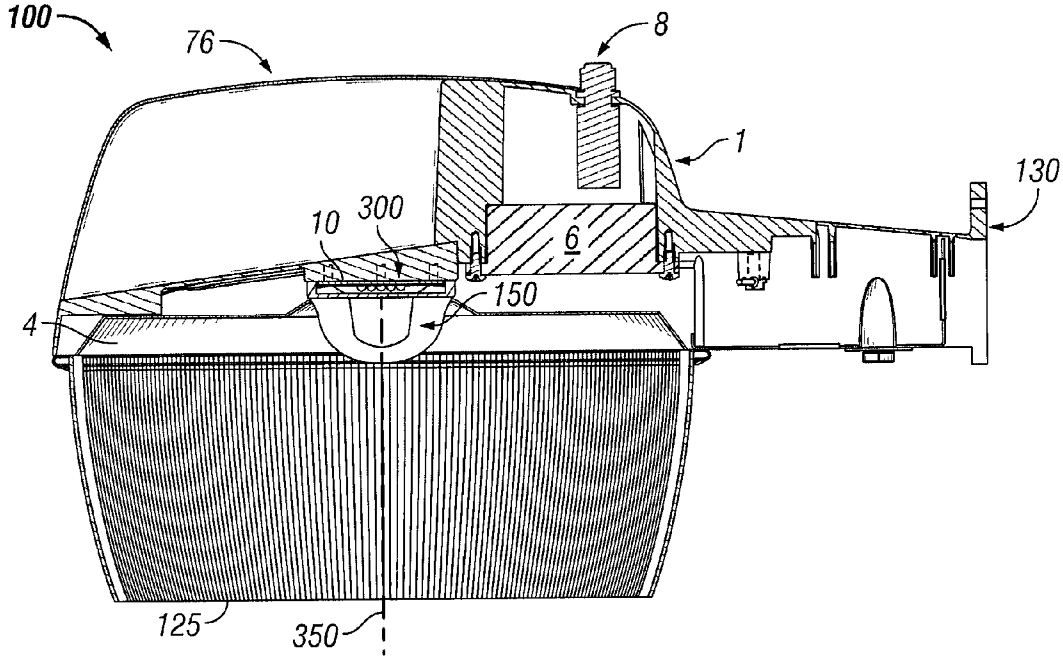


FIG. 3

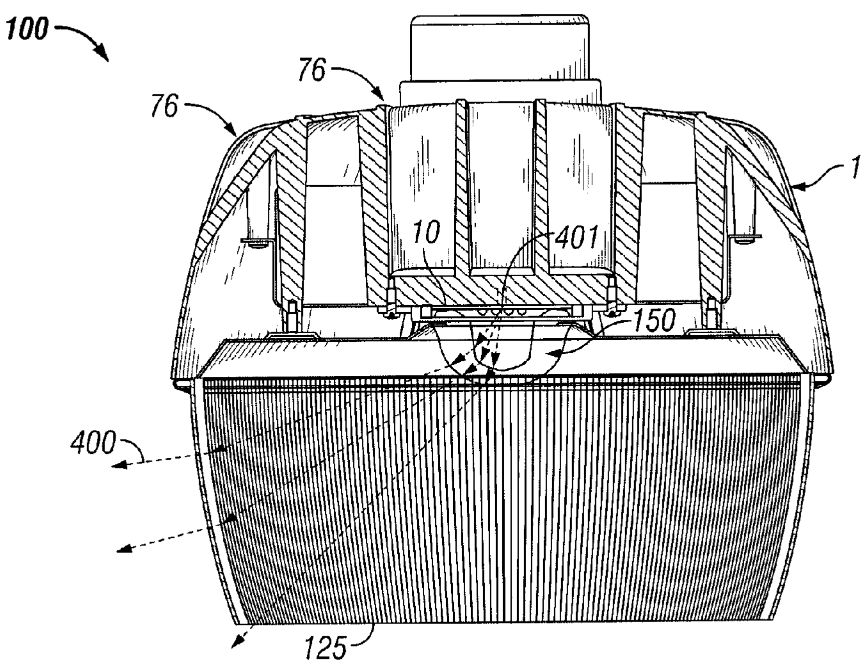


FIG. 4

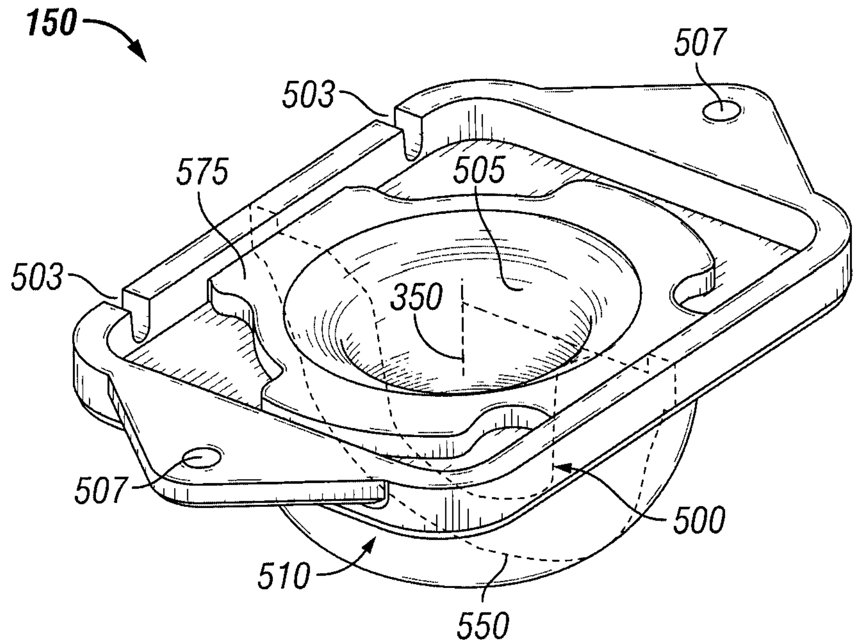

150
507
503
575
505
503
350
507
500
510
550

FIG. 5A

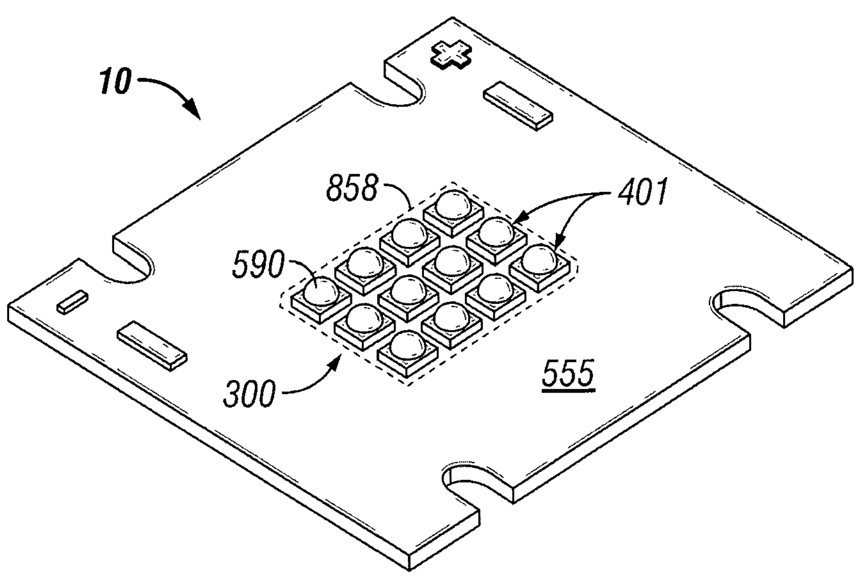
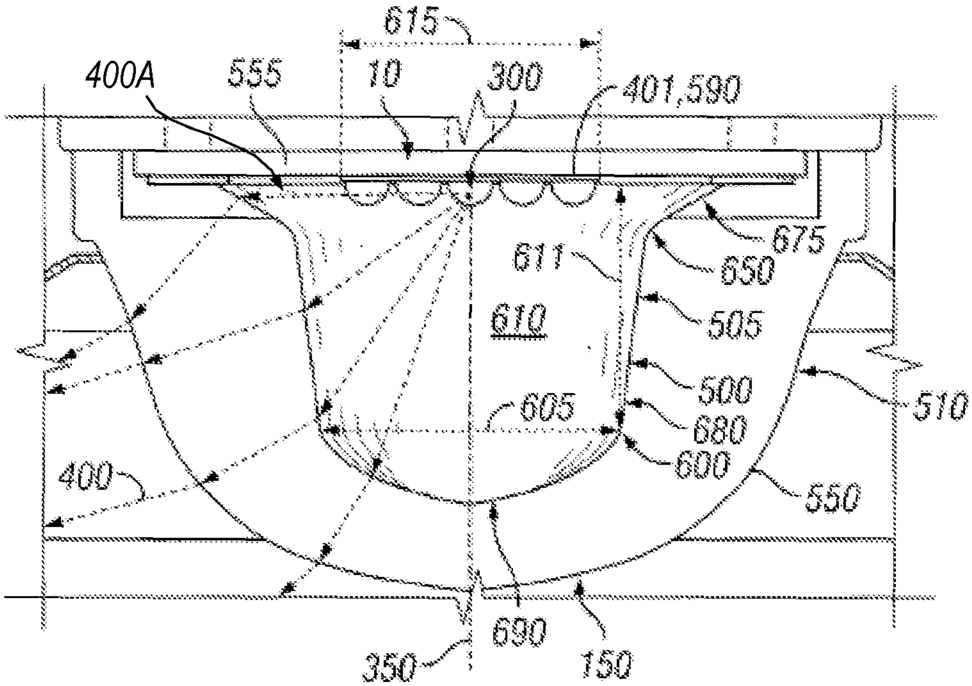
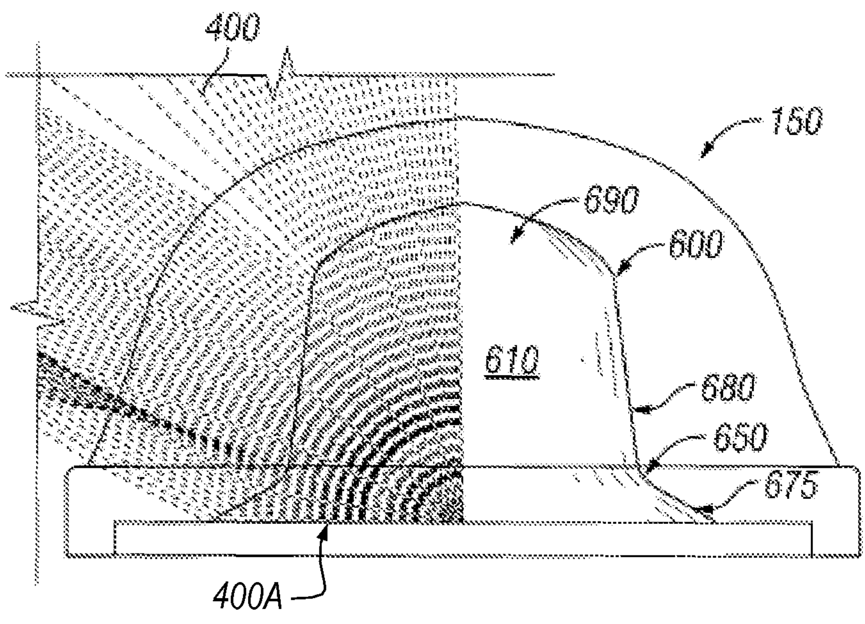

10
858
401
590
300
555

FIG. 5B



615
400A
555
10
300
401,590
675
611
650
610
505
500
510
605
680
600
400
550
690
350
150

FIG. 6



400
150
690
600
610
680
650
675
400A

FIG. 7

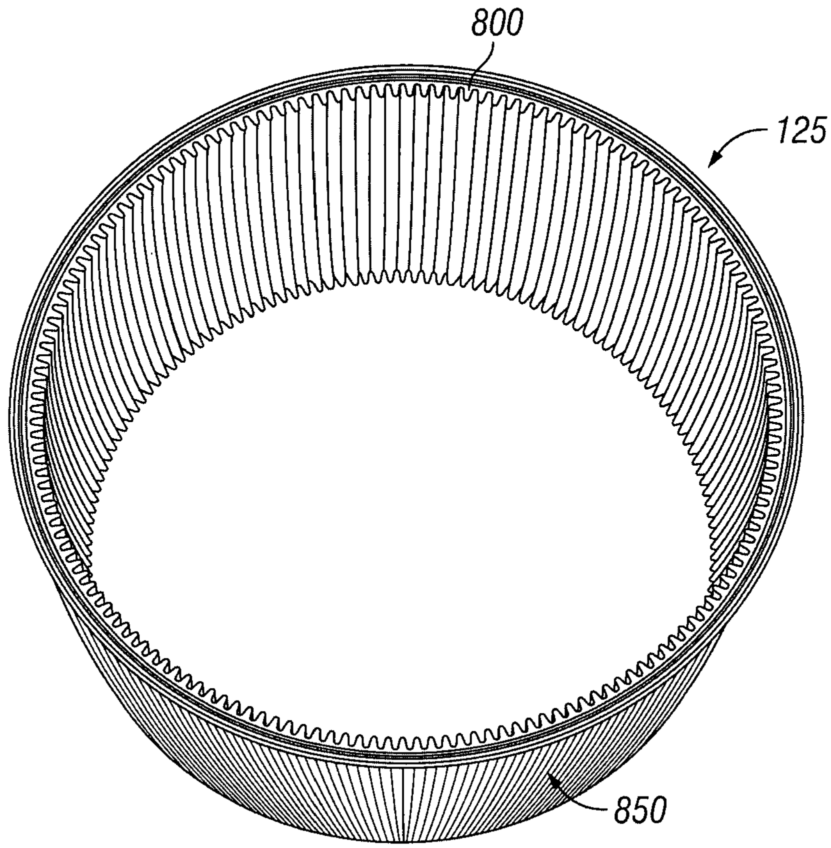


FIG. 8

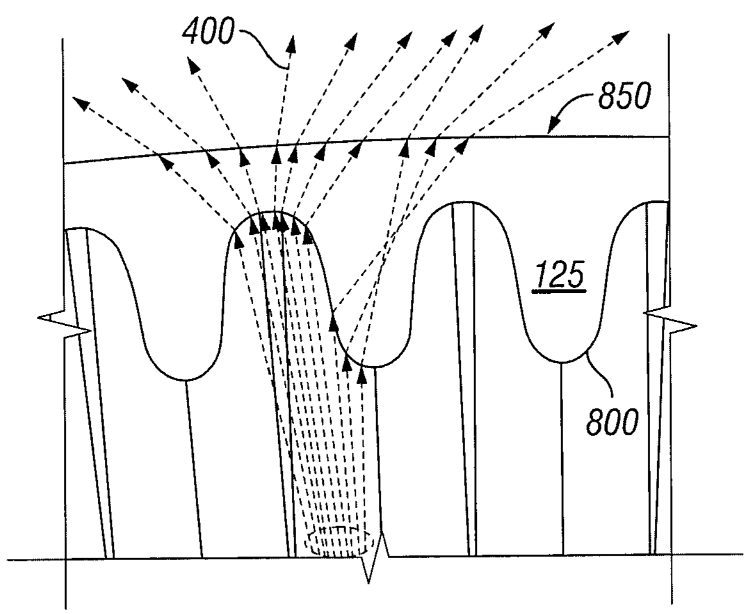


FIG. 9

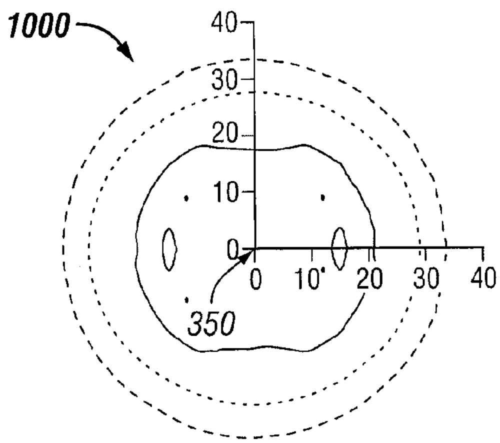


FIG. 10A

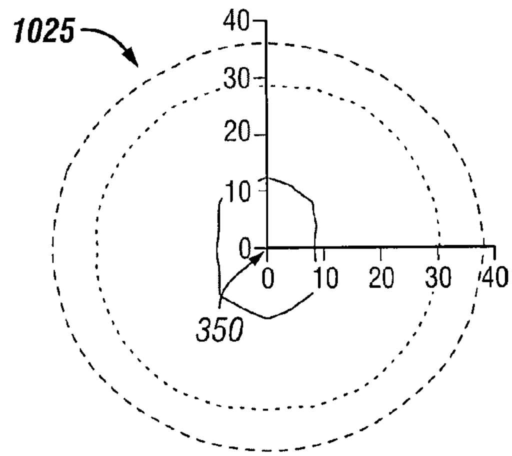


FIG. 10B

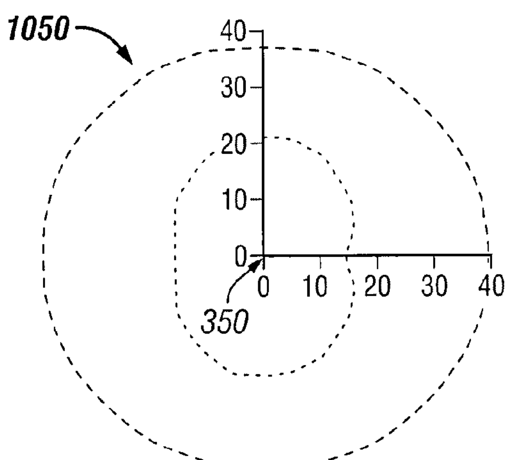


FIG. 10C

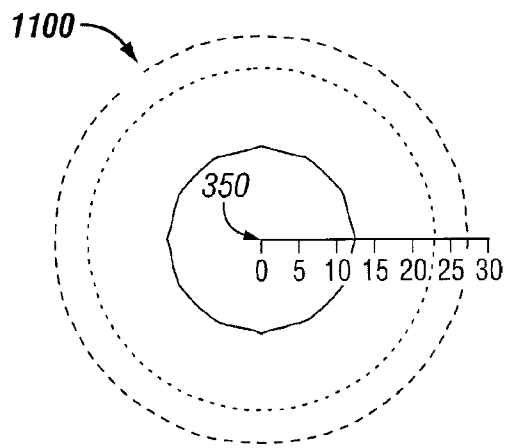


FIG. 11

LED LUMINAIRE HAVING GROOVED MODIFIER

FIELD OF THE TECHNOLOGY

The field of the technology relates generally to illumination systems and more specifically to an illumination system that includes an array of light emitting diodes ("LEDs") and at least two optics that process light emitted by the array of light emitting diodes, as may be useful for exterior lighting.

BACKGROUND

Light emitting diodes are useful for indoor and outdoor illumination, as well as other applications. Many such applications would benefit from an improved technology for managing light produced by a light emitting diode, such as forming an illumination distribution matched or tailored to application parameters.

For example, consider lighting an area with an array of light emitting diodes pointing downward, towards the ground. With many conventional light emitting diodes, the resulting illumination pattern would be relatively concentrated on the ground. However, efficiently spreading the light to provide a larger illumination area would be beneficial for many applications.

Need for improved light management is apparent. Need exists for a robust apparatus to manage light emitted by one or more light emitting diodes. Need further exists for an economical apparatus to manage light emitted by an array of light emitting diodes. Need further exists for a technology that can efficiently manage light emitted by one or more light emitting diodes, resulting in energy conservation. Need further exists for an optical device that can transform light emanating from a two-dimensional array of light emitting diodes into a desired distribution, for example redirecting light that is concentrated in one area so that the illuminated area is expanded. A capability addressing one or more such needs, or some other related deficiency in the art, would support cost effective deployment of light emitting diodes in lighting and other applications.

SUMMARY

An apparatus can process light emitted by one or more light emitting diodes to form a desired illumination distribution, for example converting light that is concentrated in one direction into a spread of light conducive to illuminating a relatively large area.

In one aspect of the present technology, a lighting system can comprise one or more light emitting diodes and two optics oriented to process emitted light. A first optic can comprise a cavity facing the light emitting diodes for subjecting emitted light to a first level of processing. A second optic can subject emitted light to a second level of processing. The second optic can comprise grooves extending lengthwise along an optical axis of the lighting system.

In another aspect of the present technology, a lighting system can comprise an array of light emitting diodes and an optic positioned to process light emitted by the light emitting diodes. The array can be distributed across a surface area, for example on a substrate. The optic can comprise a cavity that faces the array of light emitting diodes and receives light from the light emitting diodes. The optic can further comprise an outer surface that faces away from the array of light emitting diodes and that emits the received light. The cavity can be large relative to the array of light emitting diodes. For example, the cavity can have a volume exceeding the volume of a cube, where each face of the cube has a surface area equal to the surface area of the array. The optic can be utilized in the lighting system either with or without a secondary optic.

The foregoing discussion of managing light is for illustrative purposes only. Various aspects of the present technology may be more clearly understood and appreciated from a review of the following detailed description of the disclosed embodiments and by reference to the drawings and the claims that follow. Moreover, other aspects, systems, methods, features, advantages, and objects of the present technology will become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such aspects, systems, methods, features, advantages, and objects are to be included within this description, are to be within the scope of the present technology, and are to be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A, **1**B, **1**C, and **1**D, collectively FIG. **1**, are side-, back-, top-, and bottom-view illustrations of a lighting system according to certain exemplary embodiments of the present technology.

FIGS. **2**A and **2**B, collectively FIG. **2**, are exploded or assembly illustrations, in two perspective views, of a lighting system according to certain exemplary embodiments of the present technology.

FIG. **3** is partial cutaway illustration of a lighting system, taken along a mounting bracket of the lighting system, according to certain exemplary embodiments of the present technology.

FIG. **4** is a cross sectional illustration of a lighting system, taken perpendicular to the mounting bracket of the lighting system, according to certain exemplary embodiments of the present technology.

FIG. **5**A is a perspective view of a primary optic for managing light emitted by an array of light emitting diodes in a lighting system, wherein the optic is depicted as opaque to promote visualization of certain surface features, according to certain exemplary embodiments of the present technology.

FIG. **5**B is an illustration of a light emitting diode module for a lighting system according to certain exemplary embodiments of the present technology.

FIG. **6** is a cross sectional illustration of a primary optic and an associated array of light emitting diodes in a lighting system according to certain exemplary embodiments of the present technology.

FIG. **7** is a cross sectional illustration of a primary optic and associated path traces of rays in a lighting system according to certain exemplary embodiments of the present technology.

FIG. **8** is a perspective view of a secondary optic for managing light emitted by an array of light emitting diodes in a lighting system, wherein the optic is depicted as opaque to promote visualization of certain surface features, according to certain exemplary embodiments of the present technology.

FIG. **9** is a cross sectional illustration of a portion of a secondary optic and associated path traces of rays in a lighting system according to certain exemplary embodiments of the present technology.

FIGS. **10**A, **10**B, and **10**C, collectively FIG. **10**, are simulated illuminance iso-footcandle plots for a lighting system meeting a 4000 lumen specification according to certain exemplary embodiments of the present technology.

FIG. **11** is a simulated illuminance iso-footcandle plot for a lighting system meeting a 2500 lumen specification according to certain exemplary embodiments of the present technology.

Many aspects of the technology can be better understood with reference to the above drawings. The elements and features shown in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of exemplary embodiments of the present technology. Moreover, certain dimensions may be exaggerated to help visually convey such principles. In the drawings, reference numerals designate like or corresponding, but not necessarily identical, elements throughout the several views.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

A light generator can emit light. In certain embodiments, the light generator can be or comprise one or more light emitting diodes, such as an array of light emitting diodes. The light generator can emit light that presents a circular or elliptical illumination distribution on an illuminated surface. With an appropriately configured optical system, the light generator can be deployed in applications where an expanded illumination distribution is desired, for example to light a larger area. Thus, the optical system can process light emitted by the light generator to provide a larger illumination distribution on the surface, such as substantially increasing the diameter of a circular illuminance iso-footcandle line or magnifying an elliptical pattern.

In certain embodiments, such an optical system can receive light from an array of light emitting diodes, where each light emitting diode has an associated dome. The array can extend in two dimensions on a substrate, thereby covering a surface area of the substrate with a footprint. (The term "footprint," as used herein, refers to the surface space occupied by something, including interstitial spaces where a group of things are occupying surface space.) The array can be coupled to an optic comprising a cavity that receives light from the domes and an outer surface that emits the received light. For example, the domes can protrude into or be disposed in the cavity of the optic. The cavity can be sized to accommodate the array.

In certain embodiments, the cavity can have a volume that is large relative to the array. For example, suppose each face of a cube had a surface area equal to the footprint of the array. In certain embodiments, the cavity's volume can exceed the volume of such a cube. In certain embodiments, the cavity can be sufficiently large so that such a cube could fit inside the cavity. In certain embodiments, the cavity can be sized such that at least one edge of such a cube could fit in the cavity. In certain embodiments, at least one dimension of the array could fit in the cavity.

In certain embodiments, the optic having the cavity is a primary optic and is coupled to a secondary optic. Thus, the array of light emitting diodes can be coupled to an optical system comprising a primary optic and a secondary optic. In certain embodiments, the secondary optic comprises a pattern of grooves that extend along an optical axis. Light emitted from the primary optic can encounter the secondary optic and be expanded to spread the light and provide a broadened pattern of light as may be useful to illuminate a large area, among other applications.

Technology for managing light emitted by an array of light emitting diodes or will now be described more fully with reference to FIGS. **1-11**, which describe representative embodiments of the present technology. FIGS. **1-9** describe features and elements of a representative lighting system, while FIG. **10** describes representative light output characteristics for the system. FIG. **11** describes representative light output characteristics for another system having a lower lumen specification.

The present technology can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the technology to those having ordinary skill in the art. Furthermore, all "examples" or "exemplary embodiments" given herein are intended to be non-limiting and among others supported by representations of the present technology.

FIGS. **1** and **2** will now be discussed. FIG. **1** illustrates side, back, top, and bottom views of an exemplary lighting system **100** in accordance with certain embodiments of the present technology. FIG. **2** illustrates, in two perspective views, the lighting system **100** in an exemplary exploded or assembly form in accordance with certain embodiments of the present technology. In the illustrated embodiment, the lighting system **100** can be characterized as an exterior luminaire or an outdoor luminaire.

As illustrated, the lighting system **100** comprises a housing **1** that includes a bracket **130** for mounting to a wall or other site. Fasteners **7** attach an arm cover bracket **3** to the underside of the housing **1**, as part of the mounting bracket **130**. Heat sink fins **76** carry heat associated with internal electronics away from the lighting system **100**.

A photocell **8** provides automatic cut-on at dusk and cutoff at dawn. A socket **12** connects the photocell **8** to the lighting system **100**. When the lighting system **100** is deployed indoors, the photocell **8** may be bypassed or eliminated.

The lighting system **100** comprises a light emitting diode module **10** that produces light as will be discussed in further detail below. A primary optic **150**, which will also be discussed in further detail below, processes the light produced by the light emitting diode module **10**. A secondary optic **125**, also discussed below, subjects the light to a second level of processing.

Fasteners **2** attach the light emitting diode module **10** and the primary optic **150** to the housing **1**. The secondary optic **125** mounts to the housing **1** via a circular bracket **4**, thereby positioning the secondary optic **125** in an opening or aperture **220** of the housing.

A bracket **13** and associated fasteners **5** mount a light emitting diode driver **6** to the housing **1**. The light emitting diode driver **6** transforms line power to a form suitable for powering the light emitting diode module **10**. A grounding contact **14** mounts to the housing **1** via a fastener **16** and an associated lock washer **15**.

Referring now to FIG. **3**, this figure illustrates in cutaway an exemplary embodiment of the lighting system **100** in accordance with certain embodiments of the present technology.

In the exemplary embodiment shown in FIG. **3**, the primary optic **150** projects or extends through the circular bracket **4**, thereby positioning the primary optic **150** and the secondary optic **125** to collaboratively spread light emitted from the light emitting diode module **10**. As will be discussed in further detail below, the light emitting diode module **10** comprises an array **300** of light emitting diodes.

In the illustrated embodiment, the primary optic **150**, the secondary optic **125**, and the light emitting diode module **10** have a common optical axis **350**. The optical axis **350** may be associated with a distribution of emitted light and/or associated with physical structure or mechanical features.

The term "optical axis," as used herein, generally refers to a reference line along which there is some degree of rotational or other symmetry in an optical system, or a reference line defining a path along which light propagates through a system or after exiting a system. Such reference lines are often imaginary or intangible lines.

In certain embodiments, the primary optic **150** has an optical axis that is laterally offset from or tilted with respect to the optical axis of the secondary optic **125**. Moreover, the light emitting diode module **10** may have an optical axis that is laterally offset from or tilted with respect to the optical axis of the primary optic **150**, and may further be offset or tilted relative to the optical axis of the secondary optic **125**. In certain embodiments, the primary optic **150**, the secondary optic **125**, and the light emitting diode module **10** may have optical axes that are all laterally offset from one another or tilted relative to one another.

In certain embodiments, the light emitting diode module **10** may be of a form that lacks a composite optical axis along which there is rotational symmetry. In certain embodiments, the primary optic **150** may be of a form that lacks an optical axis along which there is rotational symmetry. In certain embodiments, the secondary optic **125** may be of a form that lacks an optical axis along which there is rotational symmetry.

In certain embodiments, the lighting system **100** incorporates the primary optic **150** without the secondary optic **125**. In certain embodiments, the lighting system **100** incorporates the secondary optic **125** without the primary optic **150**. Additionally, the various components and features disclosed herein may be utilized as standalone elements or integrated together to form modules or subsystems utilized in some other appropriate system or application.

The present disclosure and teaching is sufficiently rich and detailed to enable one of ordinary skill in the art to make and use a wide variety of optic embodiments by combining various features illustrated in the figures and described in text in accordance with principles of the present technology. Moreover, one of ordinary skill will be able to apply the present teaching readily to adapt the various disclosed features according to application parameters and preferences.

Referring now to FIG. **4**, this figure illustrates in cross section an exemplary embodiment of the lighting system **100** in accordance with certain embodiments of the present technology. FIG. **4** further illustrates exemplary rays **400** emitted by one of the light emitting diodes **401** in the light emitting diode module **10** and processed by the primary optic **150** and the secondary optic **125**. The primary optic **150** and the secondary optic **125** collaboratively direct the rays **400** into a wider distribution, thereby spreading the emission pattern to facilitate expanding the area illuminated by the lighting system **100**.

Referring now to FIG. **5**A, this figure illustrates in perspective view an exemplary embodiment of the primary optic **150** for managing light emitted by an array **300** of light emitting diodes **401** in the lighting system **100**, wherein the optic **150** is depicted as opaque to promote visualization of certain surface features, in accordance with certain embodiments of the present technology. In an exemplary embodiment, the illustrated primary optic **150** can be an element of the lighting system **100** illustrated in FIGS. **1**, **2**, **3**, and **4** and discussed above, and will be discussed in such representative context, without limitation.

The primary optic **150** comprises an inner profile **500** and an outer profile **550** that can be defined by the intersection of a reference plane with the primary optic **150**. In the illustrated embodiment, the inner profile **500** is formed at the intersection between the interior surface **505** and a reference plane in which the optical axis **350** of the primary optic **150** lies. In the illustrated embodiment, the interior surface **505** of the primary optic **150** is refractive. However, other embodiments of the interior surface **505** may utilize forms of light manipulation other than refraction, including without limitation reflection.

Similarly, the outer profile **550** is formed at the intersection between the exterior surface **510** and the reference plane containing the optical axis **350** of the primary optic **150**. In the illustrated embodiment, the exterior surface **510** of the primary optic **150** is refractive. However, other embodiments of the exterior surface **550** may utilize forms of light manipulation other than refraction, including without limitation reflection

As will be appreciated by those of ordinary skill having benefit of this disclosure, a "reference plane" can be thought of as an imaginary or intangible plane providing a useful aid in describing, characterizing, or visualizing something. Although illustrated in a particular position, reference planes can ordinarily be positioned in other locations that may or may not be arbitrary.

In the illustrated embodiment, the primary optic **150** comprises a combination of optically active features and optically inactive or mechanical features. The recess **575** receives the light emitting diode module **10**, and the light emitting diode module **10** may be seated in the recess **575**. Channels **503** facilitate passage of electrical leads. Holes **507** facilitate fastener-based mounting as discussed above with reference to FIGS. **1** and **2**.

In certain exemplary embodiments, the primary optic **150** is a unitary optical element that comprises molded plastic material that is transparent. The primary optic **150** may comprise poly-methyl-methacrylate ("PMMA"), polycarbonate, or an appropriate acrylic, to mention a few representative material options without limitation. In certain exemplary embodiments, the primary optic **150** can be formed of optical grade silicone and may be pliable and/or elastic, for example.

In certain exemplary embodiments, the primary optic **150** is a seamless unitary optical element. In certain exemplary embodiments, the primary optic **150** is formed of multiple transparent optical elements bonded, fused, glued, or otherwise joined together to form a unitary optical element that is void of air gaps yet made of multiple elements.

Referring now to FIG. **5**B, this figure illustrates an exemplary embodiment of the light emitting diode module **10** for the lighting system **100** in accordance with certain embodiments of the present technology. In an exemplary embodiment, the illustrated light emitting diode module **10** can be an element of the lighting system **100** illustrated in FIGS. **1**, **2**, **3**, and **4** and discussed above, and will be discussed in such representative context, without limitation.

In the illustrated embodiment of the light emitting diode module **10**, light emitting diodes **401** are organized in an array **300** mounted to a substrate **555**. In this case, the array **300** is a two-dimensional array. In various embodiments, a two-dimensional arrangement can be utilized that forms a pattern that is circular, square, rectangular, triangular, pentagon, honeycomb, or some other appropriate geometric form. In certain embodiments, a six-around-one pattern of light emitting diodes **401** can be utilized. In certain embodiments, a line of light emitting diodes **401** forming a one-dimensional array can be utilized.

As illustrated, the array **300** of light emitting diodes **401** covers a footprint **585** of the substrate **555**. The footprint **585** has a surface area. In the case of a rectangular array, surface area of the footprint **585** could be computed as length of the array multiplied by width of the array, for example.

In various embodiments, the substrate **555** can be ceramic, plastic, resin, or some other electrically compatible material. The substrate **555** can comprise a circuit board, for example. In the illustrated embodiment, the substrate **555** is flat, but may be curved or have some other appropriate geometry.

In accordance with the illustrated embodiment, each light emitting diode **401** can comprise a light emitting diode package that includes a chip-level substrate and an active area that converts electrical energy into light. The active area can comprise an optoelectronic semiconductor structure or feature and/or an aperture. A dome **590** covers and protects the active area. As illustrated, the array **300** of light emitting diodes **401** comprises a corresponding array of domes **590**, and the array **300** can be characterized as an array of domed light emitting diodes.

The dome **590** may comprise optical quality silicone, or some other appropriate material known in the art, that encapsulates the active area and transmits light. Thus, the dome **590** can provide environmental protection to the light emitting diode's semiconductor materials and emit the light that the light emitting diode **401** generates. In many embodiments, the dome **590** emits Lambertian light. Accordingly, the dome **590** may radiate light at highly diverse angles, for example providing a light distribution pattern that can be characterized, modeled, or approximated as Lambertian. In certain embodiments, multiple light emitting diode elements are covered by a single dome.

Referring now to FIG. **6**, this figure illustrates in cross section an exemplary embodiment of the primary optic **150** and associated array **300** of light emitting diodes **401** in a lighting system **100** in accordance with certain embodiments of the present technology. FIG. **6** more specifically illustrates an exemplary configuration in which the light emitting diode module **10** is mounted to the primary optic **150**. The figure further illustrates representative rays **400** that are incident on and refracted first by the interior surface **505** of the primary optic **150** and second by the exterior surface **510** of the primary optic **150**, which have respective profiles **500**, **550** as discussed above.

In the illustrated configuration, the domes **590** of the light emitting diodes **401** project towards or into a cavity **610** of the primary optic **150**. One or more of the domes **590** may extend or protrude, partially or fully, into the cavity **610**, for example. In certain embodiments, the array **300** is disposed entirely in the cavity **610** of the primary optic **150**. In certain embodiments, the array **300** is outside the cavity **610** of the primary optic **150**.

As illustrated, the cavity **610** contains a gas such as air. However, in certain embodiments, the cavity **610** may be filled with a liquid, grease, or gel. For example, in certain embodiments, a matching gel or fluid may reduce or substantially eliminate refraction at the interior surface **505** of the primary optic **150** and at the exterior surfaces of the domes **590**.

In the illustrated embodiment, the interior surface **505** of the primary optic **150** has an inner profile **500** that redirects horizontally oriented rays **400**A downward and redirects other rays **400** towards horizontal. The inner profile **500** comprises a flared peripheral region **675** that provides a refractive interface for bending horizontal rays downward and that may be characterized as slanted. A sidewall region **680** of the inner profile **500** is substantially linear and bends incident rays **400** towards horizontal. The sidewall region **680** meets with the flared peripheral region **675** in a corner **650**, which is a rounded corner in the illustrated embodiment. The inner profile **500** further comprises a bowl-shaped region **690** through which the optical axis **350** passes. The bowl-shaped region **690** meets with the sidewall region **680** in another corner **600**, which is also a rounded corner in the illustrated embodiment.

As illustrated, the interior surface **505** provides a cavity **610** having a depth **611** and width **605**. The depth **611** can be dimensioned from the top of the bowl-shaped region **690** to the closest face of the substrate **555**. The width **605** can be dimensioned between the corners **600**. As illustrated, the array **300** has a dimension across the page (and further as a two-dimensional array has another, perpendicular dimension that is not visible in the view of FIG. **6**). The dimension will be referred to in this description below as the width **615** to promote readership, without suggesting that the opposing dimension of the array **300** is bigger or smaller.

In certain exemplary embodiments, dimensions of the cavity **610** can correlate with dimensions or footprint **585** or surface area of the array **300**. For example, in certain embodiments, the width **605** of the cavity **610** is within approximately 20 percent of the width **615** of the array **300**. In certain embodiments, the width **605** of the cavity **610** is approximately equal to the width **615** of the array **300**. In certain embodiments, the width **605** of the cavity **610** is greater than the width **615** of the array **300**.

In certain embodiments, the depth **611** of the cavity **610** is within approximately 20 percent of the width **615** of the array **300**. In certain embodiments, the depth **611** of the cavity **610** is approximately equal to the width **615** of the array **300**. In certain embodiments, the depth **611** of the cavity **610** is greater than the width **615** of the array **300**.

In certain embodiments, the cavity **610** is large enough such that a cube can fit inside the cavity **610**, where each face of the cube has the surface area of the footprint **585** of the array **300** of light emitting diodes **401**. In certain embodiments, the cavity **610** has a volume that is at least as large as the volume of such a cube. In certain embodiments, the bowl-shaped region **690** of the primary optic **150** is at least as large as the footprint **585** of the array.

Referring now to FIG. **7**, this figure illustrates in cross section an exemplary embodiment of the primary optic **150** and associated path traces of rays **400** in the lighting system **100** in accordance with certain embodiments of the present technology. More specifically, FIG. **7** illustrates how the interior surface **505** and the exterior surface **510** of the primary optic **150** spread light rays **400** to broaden the area illuminated by the lighting system **100**.

Referring now to FIG. **8**, this figure illustrates in perspective view an exemplary embodiment of the secondary optic **125** for managing light emitted by an array **300** of light emitting diodes **401** in a lighting system **100**, wherein the optic **125** is depicted as opaque to promote visualization of certain surface features in accordance with certain embodiments of the present technology. In an exemplary embodiment, the illustrated secondary optic **125** can be an element of the lighting system **100** illustrated in FIGS. **1**, **2**, **3**, and **4** and discussed above, and will be discussed in such representative context, without limitation.

The illustrated secondary optic **125** has two open ends, one facing the housing **1** and one opposite. On the inside, grooves **800** extend between the two ends. In various embodiments, such grooves **800** can be refractive or reflective and may comprise fluting or prismatic surfaces.

As illustrated, the outer surface **850** of the secondary optic **125** is smooth. In certain exemplary embodiments, the secondary optic **125** is a unitary optical element that comprises molded plastic material that is transparent. The secondary optic **125** may comprise PMMA, polycarbonate, or an appropriate acrylic, to mention a few representative material options without limitation. In certain exemplary embodiments, the secondary optic **125** can be formed of glass.

Referring now to FIG. **9**, this figure illustrates in cross section a portion of an exemplary embodiment of the secondary optic **125** and associated path traces of rays **400** in the lighting system **100** in accordance with certain embodiments of the present technology. More specifically, FIG. **9** illustrates an exemplary embodiment of surface features of the secondary optic **125** manipulating light rays **400**. As illustrated the grooves **800** in combination with the smooth outer surface **850** increase axial spread of the rays **400** utilizing refraction.

Referring now to FIGS. **10**A, **10**B, and **10**C, these figures illustrate exemplary simulated illuminance iso-footcandle plots **1000**, **1025**, and **1050** for a lighting system **100** meeting a 4000 lumen specification in accordance with certain embodiments of the present technology.

The plot **1000** of FIG. **10**A illustrates simulated performance with the lighting system **100** mounted fifteen feet above the illuminated surface. The plot **1025** of FIG. **10**B illustrates simulated performance with the lighting system **100** mounted twenty feet above the illuminated surface. The plot **1050** of FIG. **10**C illustrates simulated performance with the lighting system **100** mounted twenty-five feet above the illuminated surface. The illuminated surface might be the ground, a parking lot, a grassy field, concrete, or a floor, to mention a few representative examples without limitation.

Referring now to FIG. **11**, this figure illustrates an exemplary simulated illuminance iso-footcandle plot **1100** for a lighting system meeting a 2500 lumen specification in accordance with certain embodiments of the present technology. Relative to the lighting system **100** discussed above, the simulated lighting system represented in FIG. **11** may have fewer light emitting diodes and thus output less light. The plot **1100** illustrates simulated performance with the lighting system mounted fifteen feet above the illuminated surface.

Technology for managing light emitted from one or more light emitting diodes or other appropriate sources has been described. From the description, it will be appreciated that an embodiment of the present technology overcomes the limitations of the prior art. Those skilled in the art will appreciate that the present technology is not limited to any specifically discussed application or implementation and that the embodiments described herein are illustrative and not restrictive. From the description of the exemplary embodiments, equivalents of the elements shown therein will suggest themselves to those skilled in the art, and ways of constructing other embodiments of the present technology will appear to practitioners of the art. Therefore, the scope of the present technology is to be limited only by the claims that follow.

What is claimed is:

1. A lighting system, for providing illumination along an axis, comprising:

a housing comprising an aperture through which the axis passes;

a substrate mounted at a position adjacent to or in the aperture;

an array of light emitting diodes mounted to the substrate and organized about the axis to emit light along the axis, the array of light emitting diodes comprising an array of domes;

a first optic comprising:

an interior surface that forms a cavity and that comprises a flared peripheral region that provides a refractive interface for bending downward horizontal rays emitted by the array of light emitting diodes; and

an exterior surface opposite the interior surface, wherein the first optic is mounted adjacent the array of light emitting diodes with the axis passing through the first optic, wherein at least portions of the domes are disposed in the cavity; and

a second optic comprising:

a first end oriented towards the housing and comprising a first aperture;

a second end comprising a second aperture; and

a pattern of grooves extending between the first aperture and the second aperture, wherein the axis passes through the first aperture and the second aperture.

2. The lighting system of claim **1**, wherein the interior surface of the first optic and the exterior surface of the first optic are rotationally symmetrical about the axis.

3. The lighting system of claim **1**, wherein the second optic is rotationally symmetrical about the axis.

4. The lighting system of claim **1**, wherein, the first optic has a profile defined by a cross section of the first optic taken in a plane that incorporates the axis, the profile comprising a substantially linear region that meets with a curved region to form a corner.

5. The lighting system of claim **1**, wherein the interior surface comprises:

a slanted region disposed peripherally with respect to the array of light emitting diodes;

a sidewall region disposed about the axis; and

a bowl-shaped region through which the axis passes.

6. The lighting system of claim **1**, wherein the array of light emitting diodes extends a first distance across the substrate, and

wherein, in cross section, the cavity is sized to accommodate a square having sides of length equal to the first distance.

7. A lighting system comprising:

a housing;

a planar substrate disposed in the housing;

an array of domed light emitting diodes attached to the planar substrate to cover an area of the planar substrate;

an optic comprising an interior refractive surface oriented for receiving light from the array of domed light emitting diodes and an exterior refractive surface oriented for emitting the received light;

an optical axis; and

a second optic comprising grooves extending along the optical axis,

wherein the interior refractive surface forms a cavity into which the array of domed light emitting diodes projects,

wherein the interior refractive surface comprises a flared peripheral region for bending downward horizontal rays emitted by the array of domed light emitting diodes, and

wherein the cavity has a volume that is greater than a cube having sides of surface area equal to the covered area of the planar substrate.

8. The lighting system of claim **7**, wherein the cavity comprises a rounded corner disposed to receive light from the array.

9. The lighting system of claim **7**, wherein the array of domed light emitting diodes comprises at least seven light emitting diodes, each having a respective dome.

10. The lighting system of claim **7**, wherein the cavity is large enough so that the cube could fit in the cavity.

11. The lighting system of claim **10**, wherein the interior surface comprises:

a sidewall, that is substantially flat in cross section, circumscribing an axis of the lighting system; and

a bowl-shaped region through which the axis passes.

12. The lighting system of claim **11**, wherein the bowl-shaped region and the substantially flat sidewall meet in a corner.

13. The lighting system of claim **12**, wherein the corner is rounded.

14. A lighting fixture comprising:

a housing comprising an opening configured to face an area to be illuminated;

a first optic attached to the housing and comprising an interior surface defining a cavity and an exterior surface oriented to face the area to be illuminated;

a two-dimensional array of light emitting diodes mounted adjacent or in the cavity and oriented to emit light into the cavity; and

a second optic comprising:

a first end circumscribing the first optic;

a second end opposite the first end; and

refractive grooves extending between the first end and the second end,

wherein the interior surface of the first optic is rotationally symmetric and comprises:

a flared peripheral region that provides a refractive interface for bending downward horizontal rays emitted by the two-dimensional array of light emitting diodes;

a bowl-shaped region; and

a substantially flat sidewall disposed between the flared peripheral region and the bowl-shaped region.

15. The lighting fixture of claim **14**, wherein the second optic further comprises:

an interior surface facing the first optic and comprising the refractive grooves; and

an exterior surface that is substantially smooth opposite the interior surface.

16. The lighting fixture of claim **14**, wherein the second end of the second optic is open, so that light emitted from the first optic includes first rays that are incident on the second optic and second rays that are oriented to illuminate the area while missing the second optic.

17. The lighting fixture of claim **14**, wherein the sidewall and the bowl-shaped region meet in a corner.

18. The lighting fixture of claim **14**, wherein the interior surface of the first optic has a cross sectional profile comprising an abrupt change in direction disposed between the sidewall and a bottom surface region.

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